

Claims

We claim:

1. An integrated circuit device, comprising:
 - a substrate;
 - 5 an insulating layer disposed on the substrate having a gap formed therein;
 - a liner layer that exhibits compressive stress characteristics disposed on sidewalls of the insulating layer, which define the gap, and on the substrate in the gap; and
 - 10 a contact plug that exhibits tensile stress characteristics disposed on the liner layer.

2. The integrated circuit device of Claim 1, wherein the liner layer and the contact plug comprise titanium nitride (TiN).

15 3. The integrated circuit device of Claim 1, wherein the liner layer has an amorphous crystal structure.

4. The integrated circuit device of Claim 1, further comprising:

- an ohmic layer disposed between the liner layer and the sidewalls of the insulating layer, and between the liner layer and the substrate.

20 5. The integrated circuit device of Claim 4, wherein the ohmic layer comprise titanium (Ti).

25 6. The integrated circuit device of Claim 4, wherein the ohmic layer has a thickness of about 70 Å - 100 Å.

7. The integrated circuit device of Claim 1, wherein the liner layer has a thickness of about 200 Å - 500 Å.

30 8. The integrated circuit device of Claim 1, further comprising:

- a wiring layer disposed on an upper surface of the contact plug opposite the substrate.

9. The integrated circuit device of Claim 1, wherein the wiring layer comprises a metal material.

5 10. The integrated circuit device of Claim 1, wherein the wiring layer comprises at least one of tungsten (W) and aluminum (Al).

11. The integrated circuit device of Claim 1, further comprising:
a capacitor disposed on an upper surface of the contact plug opposite the
10 substrate.

12. The integrated circuit device of Claim 1, wherein the capacitor comprises a lower electrode that contacts the upper surface of the contact plug.

15 13. The integrated circuit device of Claim 12, wherein the lower electrode comprises at least one of the following materials: W, Pt, Ru, Ir, TiN, TaN, WN, RuO₂, and IrO₂.

20 14. The integrated circuit device of Claim 1, wherein the gap is wider at a surface of the insulating layer opposite the substrate than it is at another location.

25 15. A method of forming an integrated circuit device, comprising:
forming an insulating layer on a substrate;
etching the insulating layer so as to form a gap therein, which exposes the
substrate;

30 forming a TiN liner layer on sidewalls of the insulating layer, which define the gap, and on the substrate in the gap using a method selected from the group of methods consisting of: ionized physical vapor deposition (IPVD), metal organic chemical vapor deposition (MOCVD), metal organic atomic layer deposition (MOALD), sputtering, and collimator sputtering; and

forming a TiN film on the liner layer using a method selected from the group of methods consisting of: chemical vapor deposition (CVD), atomic layer deposition (ALD), MOCVD, and MOALD.

16. The method of Claim 15, further comprising performing the following before forming the TiN liner layer:

5 forming an ohmic layer on the sidewalls of the insulating layer and on the substrate in the gap; and

wherein forming the TiN liner layer comprises forming the TiN liner layer on the ohmic layer.

17. The method of Claim 16, wherein the ohmic layer comprises Ti, and
10 wherein forming the ohmic layer comprises:

forming the ohmic layer using a method selected from the group of methods consisting of plasma enhanced chemical vapor deposition (PECVD), collimator sputtering, IPVD, and PVD.

15 18. The method of Claim 15, wherein forming the TiN liner layer comprises forming the TiN liner layer using IPVD, and wherein the TiN liner layer has an amorphous crystal structure.

19. The method of Claim 15, wherein forming the TiN film comprises
20 forming the TiN film using a method selected from the group of methods consisting of CVD and ALD and using $TiCl_4$ and NH_3 as precursors.

20. The method of Claim 15, wherein forming the TiN film comprises forming the TiN film using a method selected from the group of methods consisting of
25 MOCVD and MOALD and using tetrakis di-methyl amido titanium (TDMAT) and tetrakis di-ethyl amido titanium (TDEAT) as precursors.

21. The method of Claim 15, further comprising:

exposing the insulating layer by performing at least one of the following:
30 chemical mechanical polishing the TiN film; and
etching the TiN film.

22. The method of Claim 15, wherein etching the insulating layer comprises:

etching the insulating layer such that the gap is wider at a surface of the insulating layer opposite the substrate than it is at another location.

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23. The method of Claim 15, wherein the ohmic layer has a thickness of about 70 Å - 100 Å.

24. The method of Claim 15, wherein the TiN liner layer has a thickness of
10 about 200 Å - 500 Å.

25. A contact plug of a semiconductor device formed through an insulating film interposed between a lower conductive layer and an upper conductive layer to electrically connect the lower conductive layer to the upper conductive layer,
15 comprising:

a TiN plug having an upper surface contacting the upper conductive layer and having tensile stress;

a TiN liner contacting the TiN plug so as to surround the TiN plug along the side wall and the bottom of the TiN plug and having compressive stress; and

20 an ohmic layer contacting the TiN liner on the opposite side of the TiN plug and located between the TiN liner and the insulating film and between the TiN liner and the lower conductive layer.

26. The contact plug of Claim 25, wherein the TiN plug comprises a TiN
25 film formed by chemical vapor deposition (CVD), atomic layer deposition (ALD), metal organic CVD (MOCVD), or metal organic ALD (MOALD).

27. The contact plug of Claim 25, wherein the TiN liner comprises a TiN
film formed by ionized physical vapor deposition (IPVD), metal organic CVD
30 (MOCVD), metal organic ALD (MOALD), sputtering, or collimator sputtering.

28. The contact plug of Claim 25, wherein the TiN liner has an amorphous structure.

29. The contact plug of Claim 28, wherein the TiN liner comprises a TiN film formed by ionized physical vapor deposition (IPVD).

5 30. The contact plug of Claim 25, wherein the TiN plug has a bottom surface, which contacts the TiN liner, and the upper surface of the TiN plug has a width greater than the width of the bottom surface.

10 31. The contact plug of Claim 25, wherein the upper conductive layer comprises at least one film selected from the group of films consisting of W, Al, Pt, Ru, Ir, TiN, TaN, WN, RuO₂, and IrO₂.

15 32. The contact plug of Claim 25, wherein the upper conductive layer comprises the lower electrode of a capacitor.

33. A method for forming a contact plug of a semiconductor device, comprising the steps of:

forming an insulating film pattern for defining a contact hole exposing a conductive region on a semiconductor substrate by etching an insulating film formed on the semiconductor substrate;

forming an ohmic layer on a resulting structure after forming the insulating film pattern so as to cover an inside wall of the contact hole;

forming a TiN liner having compressive stress on the ohmic layer; and

forming a TiN plug having tensile stress on the TiN liner so that the contact

25 hole is filled.

34. The method of Claim 33, wherein the ohmic layer comprises a Ti film formed by plasma enhanced chemical vapor deposition (PECVD), collimator sputtering, ionized physical vapor deposition (IPVD), or physical vapor deposition (PVD).

35. The method of Claim 33, wherein the step of forming the TiN liner is performed by ionized physical vapor deposition (IPVD), metal organic chemical vapor

deposition (MOCVD), metal organic atomic layer deposition (MOALD), sputtering, or collimator sputtering.

36. The method of Claim 33, wherein the TiN liner has an amorphous
5 crystal structure.

37. The method of Claim 36, wherein the step of forming the TiN liner is performed by ionized physical vapor deposition (IPVD).

10 38. The method of Claim 33, wherein the step of forming the TiN plug comprises the steps of:

forming a TiN film having tensile stress on the TiN liner so as to fill the contact hole; and

15 planarizing a resultant structure on which the TiN film is formed so that the insulating film pattern is exposed.

39. The method of Claim 38, wherein the step of forming the TiN film is performed by chemical vapor deposition (CVD), atomic layer deposition (ALD), metal organic CVD (MOCVD), or metal organic ALD (MOALD).

20 40. The method of Claim 33, wherein the width of an entrance of the contact hole is substantially equal to the width of a bottom of the contact hole, through which the conductive region is exposed.

25 41. The method of Claim 33, wherein the width of an entrance of the contact hole is greater than a width of a bottom of the contact hole, through which the conductive region is exposed.

42. The method of Claim 41, wherein the step of forming the insulating
30 film pattern comprises the steps of:

forming a first insulating film pattern defining a first hole having an entrance of a first width by anisotropically etching the insulating film so as to expose the conductive region; and

forming a second insulating film pattern defining the contact hole having an entrance of a second width greater than the first width by isotropically etching a portion around the entrance of the first hole in the first insulating film pattern.

5 43. The method of Claim 42, wherein the step of isotropically etching the insulating film pattern is performed by dry etching or wet etching.

10 44. The method of Claim 33, wherein the TiN liner and the TiN plug are formed by metal organic chemical vapor deposition (MOCVD) or metal organic atomic layer deposition (MOALD).